Université d'Ottawa
Faculté de genie

Département de
Génie civil

University of Ottawa
Faculty of Engineering

Department of
Civil Engineering

uOttawa

L'Université canadienne
Canada's university

CVG 3109
SOIL MECHANICS - I
MIDTERM EXAMINATION

Question	**Max Marks**	**Marks Awarded**
1	20	
2	10	
3	40	
4	20	
Total	**100%**	

Question 1 (20 Marks)

Calculate the effective stress for a soil element at depth 5 m in a uniform deposit of soil (Figure 1). Given that specific gravity of the soil, G_s = 2.7.

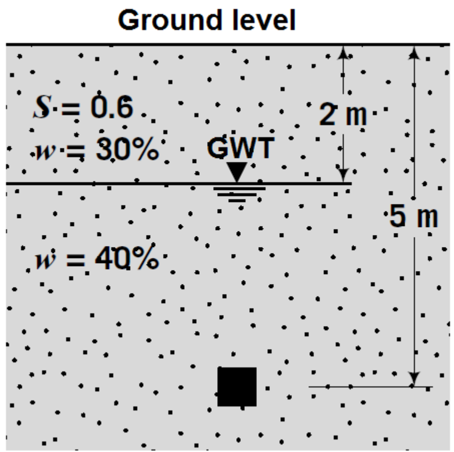


Figure 1

Solution:

First we need to determine the unit weight of the soil both above and below the ground water table. Above the GWT:

$$Se = G_s w$$

$$e = \frac{G_s w}{S} = \frac{2.7 \times 0.3}{0.6} = 1.35$$

$$\gamma = \frac{G_s + Se}{1+e}\gamma_w = \frac{2.7 + 0.6 \times 1.35}{1 + 1.35} \times 9.81 = 14.65 kN/m^3$$

Below the GWT we assume that the degree of saturation is S=100%

$$e = \frac{G_s w}{S} = \frac{2.7 \times 0.4}{1.0} = 1.08$$

$$\gamma_{sat} = \frac{G_s + e}{1+e}\gamma_w = \frac{2.7 + 1.08}{1 + 1.08} \times 9.81 = 17.83 kN/m^3$$

The total stress at 5 m depth is:

$$\sigma = 2 \times \gamma + 5 \times \gamma_{sat} = 2 \times 14.65 + 5 \times 17.83 = 118.45 kN/m^2$$

The PWP at 5m depth is:

$$u = 3 \times \gamma_w = 3 \times 9.81 = 29.43 kN/m^2$$

The effective stress at 5 m depth is:

$$\sigma' = \sigma - u = 118.45 - 29.43 = 89.02 kN/m^2$$

Question 2 (40 Marks)

For the weir embedded 3 m into a permeable soil stratum 24.0 m-thick (Figure 2),

a) Draw the flow net using Figure 2. (**20 Marks**)

b) Calculate the total rate of seepage, *q* under the weir per unit length in m^3/s. Given that the coefficient of permeability of the soil, $k = 1.0\times10^{-5}$ m/sec. (**5 Marks**)

c) Calculate the effective stress at Point A if $\gamma_{sat} = 20$ kN/m^3. (**15 Marks**)

Solution:

a) The flow net (N_f=4, N_d=14) is shown:

$$Total\ Head\ Loss = 10 - 1.5 = 8.5m$$

$$\Delta h = \frac{8.5}{14} = 0.607m$$

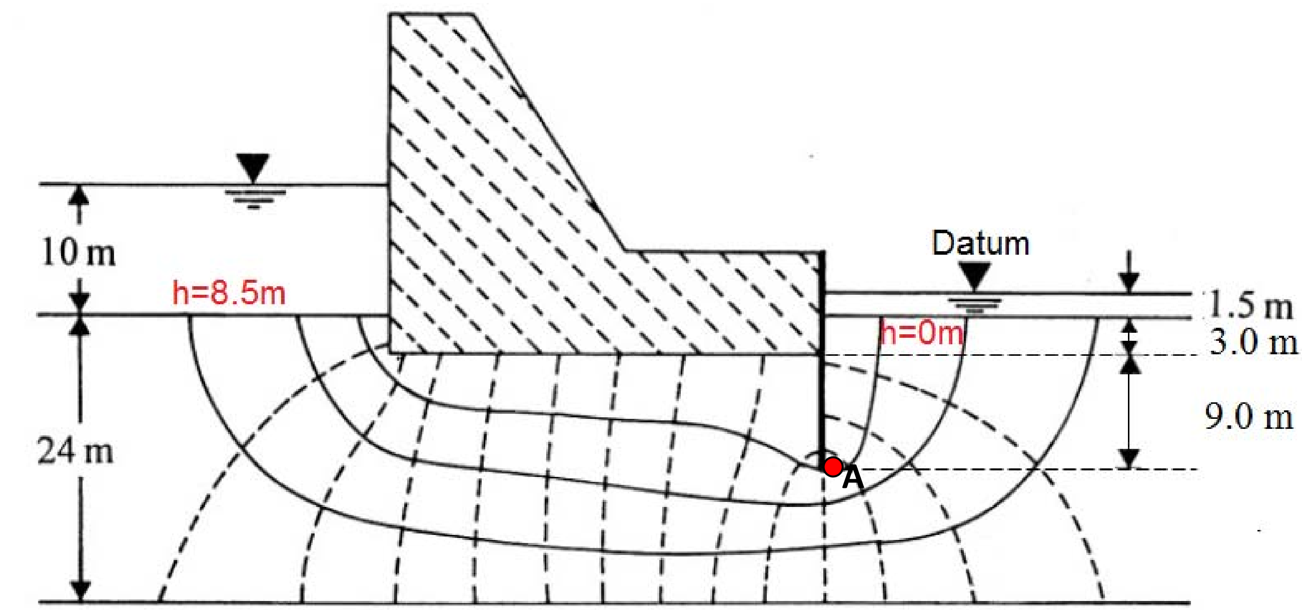


Figure 2

b) The total rate of seepage, *q* under the weir per unit length in m^3/s (unit width).

$$q = kh_w\left(\frac{N_f}{N_d}\right) = (1.0\times10^{-5})(8.5)\left(\frac{4}{14}\right) = 2.429\times10^{-5} m^3/s/m$$

c) To determine the effective stress at point A, we need to calculate the pore water pressure at A.

$$total\ head\ @\ A = 0 + 4\times\Delta h = 4\times0.607 = 2.43m$$

$$h_{w(A)} = total\ head - elevation\ head = 2.43 - (-13.5) = 15.93m$$

$$u_A = h_{w(A)} \times \gamma_w = 15.93 \times 9.81 = 156.27 kN / m^2$$

Total stress at A:

$$\sigma_A = 1.5\gamma_w + 12\gamma_{sat} = 1.5 \times 9.81 + 12 \times 20 = 254.72 kN / m^2$$

Effective stress at A:

$$\sigma'_A = \sigma_A - u_A = 254.72 - 156.27 = 98.45 kN / m^2$$

Question 3 (25 Marks)

At a vertical stress of 200 kPa, the void ratio of a saturated clay soil sample tested in an oedometer was 1.52 (point A). An increment of vertical stress of 150 kPa compressed the sample to a void ratio of 1.43 (point B). Assuming that the clay sample is normally consolidated,

a) Determine the compression index, C_c, of the soil. (**5 Marks**)

b) The sample was then unloaded to a vertical stress of 200 kPa, and the void ratio increased to 1.45 (point C). Determine the swelling (recompression) index, C_s. (**5 Marks**)

c) What is the overconsolidation ratio (OCR) of the soil at point C? (**5 Marks**)

d) If the soil specimen were reloaded to a vertical stress of 500 kPa, what void ratio would be attained (point D)? (**5 Marks**)

e) Draw a sketch of the soil response on a plot of vertical effective stress (log scale) versus void ratio and show the locations of points A, B, C, and D. Use the graph paper provided (Figure 3). (**5 Marks**)

Solution:

a) Determine the compression index, C_c, of the soil.

The compression index, C_c, of the soil is the slope of AB (see the Figure in part e).

$$C_c = \frac{-(1.43 - 1.52)}{\log(350/200)} = 0.37$$

b) Determine the swelling (recompression) index, C_s (or C_r) is the slope of BC (see the Figure in part e).

$$C_r = \frac{-(1.43 - 1.45)}{\log(350/200)} = 0.08$$

c) What is the overconsolidation ratio (OCR) of the soil at point C?

$$\text{Past maximum vertical effective stress:} \quad \sigma'_{zc} = 350 \text{ kPa}$$

$$\text{Current vertical effective stress:} \quad \sigma'_z = 200 \text{ kPa}$$

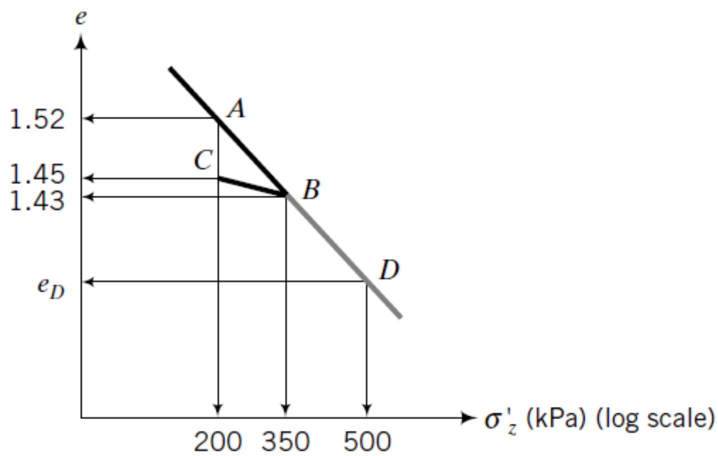
$$\text{OCR} = \frac{\sigma'_{zc}}{\sigma'_z} = \frac{350}{200} = 1.75$$

d) If the soil specimen were reloaded to a vertical stress of 500 kPa, what void ratio would be attained (point D)?

The void ratio at 500 kPa is the void ratio at point D on the virgin compression line (see the Figure in part e).

$$e_D = e_B - C_c \log\left(\frac{500}{350}\right) = 1.43 - 0.37 \log 1.43 = 1.37$$

e) Draw a sketch of the soil response on a plot of vertical effective stress (log scale) versus void ratio and show the locations of points A, B, C, and D.



Question 4 (15 Marks)

A 3 m high embankment is to be constructed as shown in Figure 4. If the unit weight of fill used in the embankment is 19.0 kN/m^3, calculate the vertical stress increase due to the embankment loading at points P_1, P_2, and P_3. Use the chart on the last page of this exam to determine the influence value, I.

Solution:

The embankment is divided into blocks as shown in Figure 4. The details of each block for making use of the influence factor chart are summarized in the table below.

$q = \gamma H = 19 \times 3 = 57$ kN/m^2, $z = 3$ m

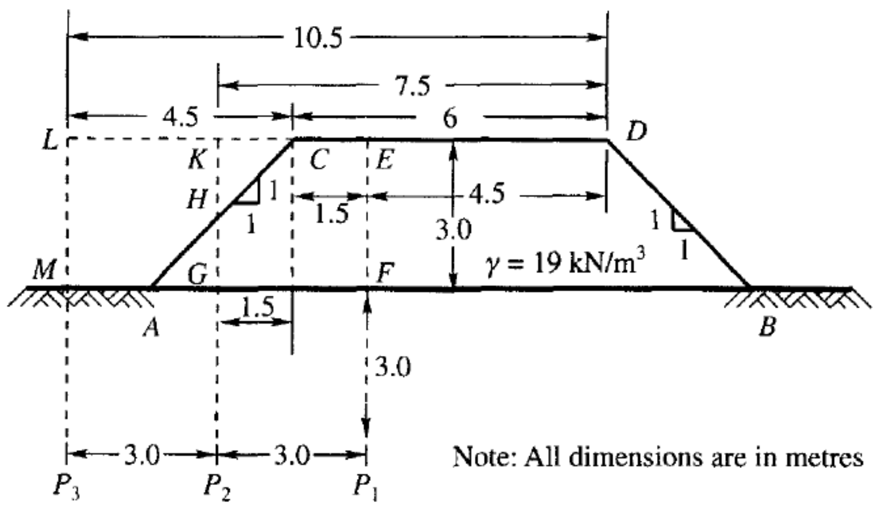


Figure 4

Point	Block	B_1 (m)	B_2 (m)	B_1/z	B_2/z	I_2
P_1	*ACEF*	1.5	3	0.5	1	0.39
	EDBF	4.5	3	1.5	1	0.477
P_2	*AGH*	0	1.5	0	0.5	0.15
	GKDB	7.5	3	2.5	1.0	0.493
	HKC	0	1.5	0	0.5	0.15
P_3	*MLDB*	10.5	3.0	3.5	1.0	0.498
	MACL	1.5	3.0	0.5	1.0	0.39

Vertical stress σ_z

At point P_1, $\sigma_z = (0.39 + 0.477) \times 57 = 49.4$ kN/m^2

At point P_2, $\sigma_z = 0.15 \times (57/2) + 0.493 \times 57 - 0.15 \times (57/2) = 28.1$ kN/m^2

At point P_3, $\sigma_z = (0.498 - 0.39)\, 57 = 6.2$ kN/m^2